§16. Neutronics Investigation on a Flibe/V-alloy Blanket Concept

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A blanket concept using molten-salt Flibe and V-4Cr-4Ti alloy was proposed for FFHR (FFHR-FV), in which doping of MoF_6 or WF_6 into Flibe was proposed for corrosion protection of the wall surfaces by precipitation of Mo or W, and for reduction of the tritium inventory by enhancing the reaction from T_2 to TF which is more soluble in Flibe [1].

This study investigates the neutronics performance of this concept assuming the blanket with the simple torus structure of FFHR-FV receiving the neutron wall loading of 1.5 MW/m^2. The procedure for the calculation was shown in Ref. [2]. Assuming the rector power of 3 GWth, the reaction of the transmutant tritium with MoF_6 and WF_6 results in the precipitation of 2.7 kg of Mo and 5.1 kg of W per day, respectively. They would be removed from Flibe out of the blanket area by cold traps or other recovery systems. In the calculation, two cases, no recovery and 99% recovery, were assumed for the Mo or W precipitates.

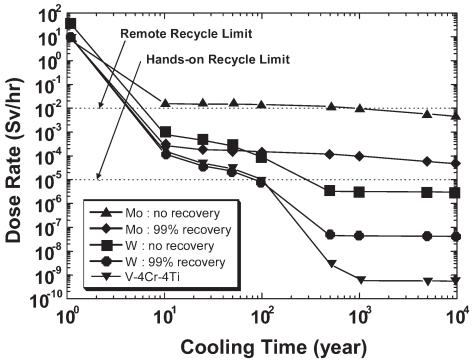

Fig. 1 Dose rate of the blanket as a function of the cooling time after 30 years' operation. The blanket parameter of FFHR-FV [2] was used. Two cases of no recovery and 99% recovery of Mo or W precipitates were assumed. The recycle limits are also indicated.

The dose rate of the blanket as a function of the cooling time after 30 years' operation is given in Fig. 1. The blanket without any precipitation of Mo or W can satisfy the hands-on recycle limit after 100 years' cooling. In the case of MoF_6 doping, Mo precipitation results in the radiation level where recycling is almost unfeasible if any recovery is not carried out. 99 % recovery of Mo precipitates results in potential recycling in some shielded conditions. In the case of WF_6 doping, the hands-on recycling limit is fulfilled only after several hundreds of years without any recovery. In contrast, the hands-on recycle limit is satisfied after 100 years' cooling with 99% recovery, which is similar to the case without any precipitates. Therefore, the doping of WF_6 has a large advantage over that of MoF_6 with respect to the induced radioactivity and recycling capability.

Fig. 2 compares the local Tritium Breeding Ratio (TBR) as a function of the operation years. Initial TBR of 1.261 continues to decrease with accumulation of Mo or W in the blanket. However, since the change in TBR is only ~0.01 after 30 years' operation in maximum case, influence of Mo or W precipitation to TBR seems to be negligible.

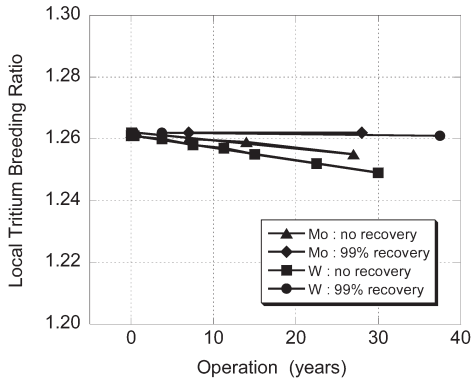

Fig. 2 Local Tritium Breeding Ratio (TBR) as a function of the operation time. Two cases of no recovery and 99% recovery of Mo or W precipitates were assumed.

Fig. 3 shows the transmutation products in Mo and W during the operation. Mo and W coatings, once formed during the initial operation, will change into Mo-Nb-Tc-Ru alloy and W-Ta-Re-Os alloy coating during the succeeding operation, respectively. The chemical change in the coating could influence the corrosion protection ability.

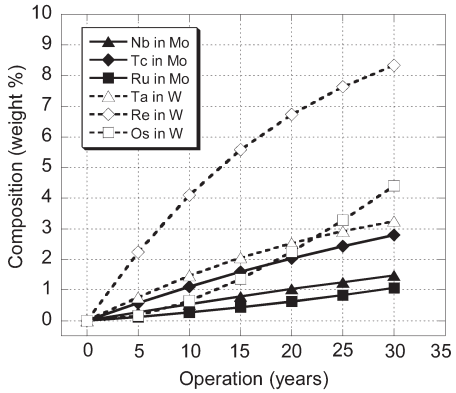

Fig. 3 Compositional change of Mo and Nb in the blanket during the operation.

Some prediction of the stability of the alloy is possible according to the thermodynamic data. Based on the free energies for fluoride formation derived from MALT-2 database, the free energies are larger for RuF_5 and ReF_6 than for MoF_6 , WF_6 and HF. This suggests that Ru and Re may be stable in Flibe, whereas Nb and Ta may be unstable in Flibe. Considering relatively high production rate, Ta in W could degrade the stability of the coating.

References

[1] T. Muroga, A. Sagara, T. Tanaka, Z. Li and D. Sze, Fusion Science and Technology, in press.
[2] T. Muroga, T. Tanaka and A. Sagara, Fusion Engineering and Design, 81 (2006) 1203-1209